COMPUTER-BASED INSTRUCTIONAL RESEARCH AND DEVELOPMENT IN THE AIR FORCE: AN OVERVIEW

The Air Force has been involved in the application of computer technology to training for a considerable time. One of the very early efforts was the computer-based training capability developed for on-the-job training of operators within the semi-automatic ground environment (SAGE) system in the mid 1950's. The basic notion of using an operational computer to provide on the job training was later extended to the Air Force computer directed training system (CDTS). This system, which is still in use, provides CAI delivered training for a variety of base level support personnel.

Although preliminary concept studies were conducted during the 1960's, regarding the potential of "automated" instruction and the use of computers in training, it was not until the early 1970's that the Air Force began a long range research and development thrust in computer-based instruction. Initial efforts included an assessment of the application of CAI at that time and demonstration studies of the use of CAI to teach Air Force technical courses. Other related investigations explored the feasibility of computer controlled adaptive testing models, artificial intelligence based troubleshooting and instructional management. The major Air Force CBI research and development effort during the 1970's was the Advanced Instructional System (AIS). This system was designed to provide the capability to administer and manage individualized instruction on a large scale. A major state-of-the-art advancement was a software capability which provided a full range of CBI functions including course development and presentation, resource allocation and scheduling, and instructional management. The papers within this section are representative of the current directions in Air Force CBI research and development.

The views, opinions, and/or findings contained in this report are those of the author and should not be construed as an official Department of the Air Force or Department of Defense position, policy, or decision, unless so designated by other official documentation.

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DESK TOP TRAINER: TRANSFER OF TRAINING OF AN AIRCREW PROCEDURAL TASK

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This paper describes a trial-of-concept experiment conducted to evaluate the utility of a microcomputer graphics-based desk top trainer (DTT) for aircrew training purposes. Air Force instructor and student pilots were trained to program the computer controlled, air-to-ground weapons, on an F-16 aircraft. An experimental group (n = 20) was trained in the procedure using a microcomputerized desk top trainer while a control group (n = 20) was trained using a self-instructional illustrated text. Transfer of training effects were assessed using tasks on the actual aircraft system as the criterion, with time and number of errors as the dependent measures. The experimental group was able to complete criterion tasks in significantly less time and with significantly fewer errors, than the control group. A transfer effectiveness measure (TEM), computed for both dependent measures, was found to be significant for the experimental group. Results support the application of microcomputer graphics systems as low-cost alternative training systems for the procedural aspects of aircrew training.

The cost of training Air Force aircrews continues to rise. Energy inflation, developmental and operational costs now make flight simulators and training devices nearly as expensive as the aircraft themselves. Although simulators are in widespread use within the Air Force, there is an urgent need for less costly training alternatives.

The transfer of learning from a simulated, training, environment to an operational environment is a major issue. Questions relating to task fidelity (e.g. how closely a training system must approximate an actual system in terms of performance functions, appearance, etc.) are at issue whenever new technology is considered. With cost as a primary consideration, one approach to improving training is to optimize efficiency during a pre-simulator phase by exploiting least-cost technologies.

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Related Literature

Little is known about the potential transfer of learning benefits of microcomputerized trainers for aircrew tasks as measured on actual aircraft equipment. The scarcity of empirical evidence is particularly troublesome in view of the widespread interest in the applying of microcomputer-based systems, as low-cost devices, to aircrew training.

The relative effectiveness of computer assisted instruction (CAI) versus illustrated program text was examined in this study. The text version of training provided a convenient, low cost, alternative media representative of much of the material presently used in aircrew academic settings. Related research supports the superiority of CAI over text or other training media. (Deignan et al, 1980; Robinson, Tomblin and Houston, 1981; Buck, 1982; and Fisher, 1982). Subjects in those studies, however, were dissimilar to those used in the present investigation (i.e. neither college graduates nor pilots), and therefore precluded generalizability of results.

The objective of this study, therefore, was to evaluate transfer of learning to actual aircraft equipment from training using a microcomputer-assisted interactive graphics trainer in comparison

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14. ABSTRACT
This paper describes a trial-of-concept experiment conducted to evaluate the utility of a microcomputer graphics-based desk top trainer (DTT) for aircrew training purposes. Air Force instructor and student pilots were trained to program the computer controlled, air-to-ground weapons, on an F-16 aircraft. An experimental group (n = 20) was trained in the procedure using a microcomputerized desk top trainer while a control group (n = 20) was trained using a self-instructional illustrated text. Transfer of training effects were assessed using tasks on the actual aircraft system as the criterion, with time and number of errors as the dependent measures. The experimental group was able to complete criterion tasks in significantly less time and with significantly fewer errors, than the control group. A transfer effectiveness measure (TEM), computed for both dependent measures, was found to be significant for the experimental group. Results support the application of microcomputer graphics systems as low-cost alternative training systems for the procedural aspects of aircrew training.

15. SUBJECT TERMS
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to an illustrated programmed text containing equivalent training content, using subjects who would typically perform the criterion tasks.

METHOD

Experimental Design

A modified post-test only control group design (Campbell and Stanley, 1971) was used to compare group performance on two dependent measures: mean time to task completion and mean error rate per task. In addition, a general linear model employing training time as a covariate (Pennell, note 1), was used to assess transfer of training effects. The model was:

$$Y' = a + b_1G + b_2X + b_3(GX) \qquad (1)$$

Where Y' = Predicted value of the dependent variable,
a = intercept,
G = design or dummy variable expressing group membership,
X = covariate,
b_1-b_3 = Regression weights,
GX = Interaction.

If b_3 is significant, the within group regressions are not homogenous. Then it can be argued that a transfer effectiveness measure (TEM) should be a function of the separate, non-homogenous regression weights. However, when b_3 is not significant (i.e. the regression is homogenous), a natural TEM is:

$$\text{TEM} = 1 - \frac{Y'_e}{Y'_c} \qquad (2)$$

(assuming b_1 is significant). TEM varies between 0 and 1 and measures the superiority of experimental training for a fixed amount of training time.

This methodology was used rather than the transfer effectiveness ratio (TER) reported by Roscoe (1971, 1972) and Payne (1982) because these models assume no pre-training of the control group. In Roscoe's treatment, this assumption is used as a basis for the TER computation. Roscoe uses the value for the control group's criterion score as the baseline for the TER evaluation. Since the present experiment was planned with the control group receiving a version of training, neither TER nor the percent of transfer of learning discussed by Payne was appropriate for the assessment of transfer of training in the present study.

Figure 1.

Figure 2.

Subjects

Instructor pilots (n = 20) and student pilots (n = 20) assigned to undergraduate pilot training at Williams AFB participated as subjects. None had knowledge of the F-16 aircraft stores management system. Subjects were randomly assigned to groups.

Experimental Tasks

The task was programming the air-to-ground weapons profile mode of the F-16 stores management set. The stores management set is a computer program within the aircraft fire control computer which permits the pilot to preset various release parameters associated with air-to-ground weapons prior to release of the weapons during a mission. The pilot controls the system by the stores control panel (SCP) which is about five inches square and consists of push button controls surrounding an illuminated alphanumeric display (see Figures 1 and 2). By pushing buttons in the proper sequence, the pilot can select, inventory, or modify delivery parameters for up to five separate weapons. The criterion tasks used in this experiment consisted of programming each of five weapons according to specific release parameters.

Performance Measures

Time on task and number of input errors were the performance measures. The criterion test consisted of five, 5" x 7" cards, each containing a different specification for a weapon delivery profile. Each task description specified weapon type, specific release parameters, and required subjects to program the system by control inputs (i.e. button pushes) on the stores control panel in a cockpit environment. None of the tasks in the criterion test were identical to any examples or practice items used in either version of the training materials.

Training Materials

The display functions of the stores control panel were modeled graphically on the desk top trainer. A computer program was developed to simulate all the relevant functions of the aircraft system for the air-to-ground weapons delivery profile mode. A self-instructional training sequence was developed so that subjects could receive all pertinent information, and interact as necessary with the system to learn proper task procedures. Programmers used the F-16 stores management set software from the Advanced Simulator for Pilot Training as a reference in developing experimental software for the desk top trainer. Prior to the conduct of the study the system was operated by experienced F-16 pilots as a validation of technical content.

An illustrated, programmed text was also developed containing task information equivalent to that in the desk top trainer version. The illustrated text was prepared using the F-16 Avionics manual as a content guide. The text and illustrated material corresponded closely with the computerized instruction, but without the manual interactivity feature. The text was illustrated to provide clear visual representations of each step or procedure, exact control inputs to be made, and system reactions to each control input. The illustrated text was reviewed and edited by content experts and tried out by several pilots. The approximate time required to complete instruction with each version of training was verified prior to data collection as a control for floor effects.

Apparatus

The desk top trainer (Figures 3 and 4) was based upon a 64K-byte, random access memory, microcomputer. The system used an S100 buss and dual mini-floppy disk drive. The primary display mode was a color graphics display. Programming and alphanumeric texts were provided using a standard terminal. Interface with the graphics display was achieved through a touch panel installed upon the graphics display and integrated with the computer.

In the stores control panel configuration, the graphic representation of the panel was about 40 percent larger than the actual aircraft equipment. The training text was displayed on the terminal cathode ray tube.

A functional spare F-16 stores control panel was used for criterion testing. This panel was contained in the F-16 cockpit of the Advanced Simulator for Pilot Training and permitted capture of performance data. Because the system was, in fact, actual aircraft equipment and functioned precisely as does the aircraft system stores control system, the assumption of equivalence (i.e. high fidelity), between the simulator environment and the aircraft appeared reasonable in the present experiment.

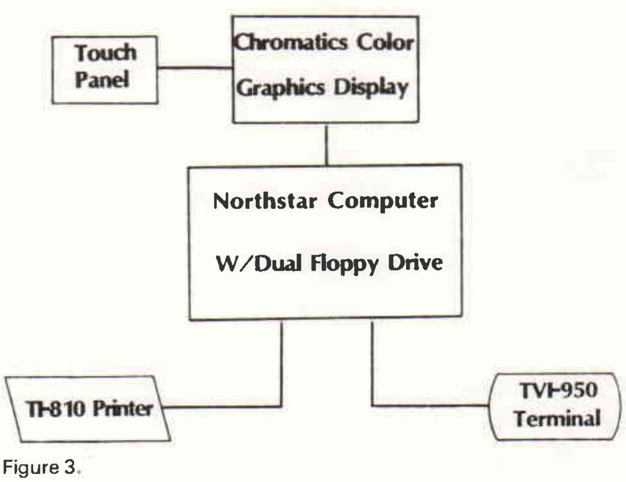

Figure 3.

Figure 4.

Procedures

Subject scheduling for experimental training and randomized assignment to groups were predetermined. Each subject was given a standard text-inbriefing and asked to provide some basic demographic data, regardless of group assignment.

Subjects in the experimental group were seated at the desk top trainer and given a brief introduction which included operating instructions after which the experimental training proceded. At the end of training, subjects were allowed to ask questions about lesson content.

The control group received the self-instructional illustrated text and proceeded with the programmed instruction. At the conclusion of the instruction, the subjects were allowed to ask questions about the procedure and clarify points in the lesson. The time from start to completion of instruction was timed for all subjects in both groups.

Following completion of instruction, all subjects were escorted directly to the simulated F-16 cockpit for criterion testing with each receiving the same tasks. They were shown the cockpit, seated, and briefed on the stores control panel. Subjects were told to execute each of the five tasks contained on the task cards one at a time, as quickly as possible, but with as few errors as possible. The time to complete each task and the total elapsed time for the entire test were recorded. The order of the five tasks was the same for all subjects. Information displayed on the stores control panel was the same at the start of each task for all subjects.

Error Analysis

In addition to time measures, the number of control inputs made by each subject for each task was recorded. The programming of each task required a specific sequence of pushed button inputs. Because each task was initiated with the same information displayed on the stores control panel, there was a most direct or shortest "path" to correctly programming each profile, (i.e., the minimum number of button inputs to affect the correct alphanumeric display). Error inputs, therefore, could be tabulated simply by subtracting the number of inputs required by the subject from the number required for errorless execution of the task. A list of the minimum number of inputs per task is shown in Table I.

Table 1. Shortest (Most Correct) Path to Criterion.

Task Number	1	2	3	4	5
Buttons Required	13	14	3	9	8

RESULTS

The comparison of group performance on the criterion test is summarized in Figure 5. The experimental group mean completion time, per task, for the five tasks in the criterion test, was 38.9 seconds in comparison to 47.5 seconds for the control group (standard error of mean = 5.2 sec). An alpha level of .05 was selected. The F-value for this comparison was 6.82 (ds = 1, 39; p = .013). The mean errors (excess button pushes) made by the experimental group was .93 per task compared to 3.3 per task for the control group (standard error of mean = .98). The obtained F-value for this comparison was 14.17 (ds = 1, 39; p <.001).

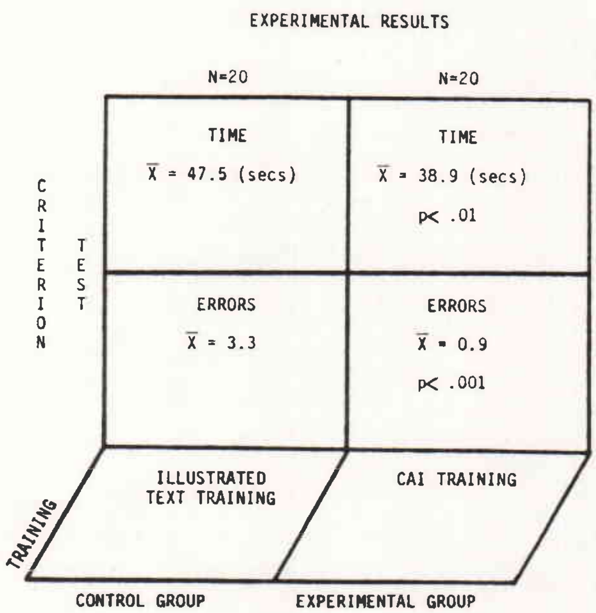

Figure 5.

The linear model (1) was evaluated for both dependent measures (i.e., time to task completion and errors). In both cases the within group regressions were homogenous and the group effects (b_1) were significant. Using equation (2), therefore, the TEM for time and errors, both statistically significant, was .183 and .182 respectively.

DISCUSSION

This experiment was intended primarily as a trial-of-concept of microcomputer technology for aircrew training. The purpose was to assess the effectiveness of a desk top trainer as a vehicle to train cockpit procedural tasks. As a part of this assessment, experimental training was compared to a version of instruction often used in current academic training environments. Comparision of criterion performance differences between the two groups, and the differential transfer of training effects to criterion performance on aircraft equipment, demonstrated the superiority of the desk top trainer instruction. The desk top trainer was more effective than the text version, presumeably because the system gave subjects the opportunity to actually engage in the tasks in a manner nearly identical to that of the cockpit environment.

In order to fully test the contribution of the interactivity element, however, an empirical comparison would be required between different versions of the CAI, one with and one without interactivity (e.g. Avner, Moore, & Smith, 1980). The present study provided a promising initial examination of an application of a "micro" for an aircrew procedural task. The results also suggested the appropriateness of a formal comparison of a desk top trainer against aircraft equipment itself. The results of such a test would provide a definitive baseline to establish the actual cost avoidance potential of the desk top trainer for an operational training context. Such an effort was clearly outside the scope of the present data.

It seems reasonably certain that microcomputers can be effectively applied to a variety of aircrew tasks or part-tasks. But within this generalization there remains a great deal to be learned about optimizing technological applications. Important issues related to courseware development, cost effectiveness, software standardization and management, effectiveness evaluation, and others will require systematic investigation before instructional technology can be applied with confidence.

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